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Interdisciplinary Environmental Approaches to the Evolution of Late Pleistocene and Holocene Periods in the Western Gulf of Maine

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With growing concerns around climate change and sea-level rise, tracking these changes and pinpointing environmental trends are of the upmost importance. In the Gulf of Maine, sea-level rise and warming waters will have a major impact on the fishing and agricultural industries that are so vital to the region. In order to help prepare for these environmental transformations, we have looked to the past. The landscape of the Gulf of Maine region has evolved significantly since the late Pleistocene. Sea-level variations, habitat and species changes, and human use and modification of the landscape have had a large impact on the region. We have focused on two strategically selected areas of Casco Bay that have been greatly affected by the ecological changes that have threatened our coastline for centuries. The two locations have been used to expand prior datasets to help strengthen past theories about changes in the Gulf of Maine over the last several thousand years. In order to get a full range of data to analyze the evolving landscape, we have utilized a variety of techniques: vibracoring of intertidal and subtidal environments for subsurface sediment retrieval, radiometric assessment and x-ray fluorescence analysis for the chemistry of sediment samples, and identification of marine and terrestrial species in the vibracored samples. The collection process and analysis will provide data for research into the historical and evolving coastal landscape and will be utilized for years to come in USM courses.

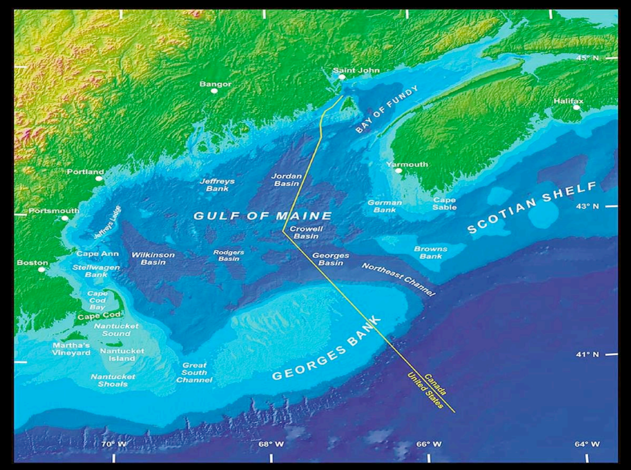

Figure 1. Map of the Gulf of Maine and other surrounding features (NOAA, 2017).

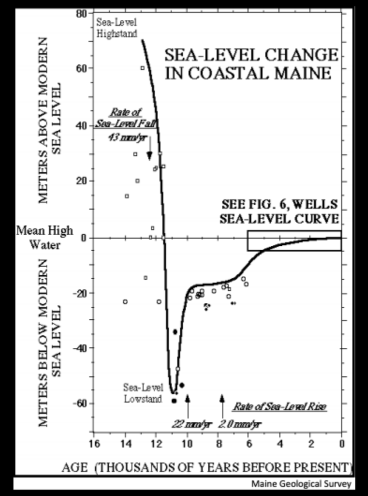

Figure 2. Sea-level curve of coastal Maine over the 12k+ years (Belknap et al., 1987).

READY SITE/MURRY MARSH

The Ready Site/Murry Marsh, is on private property and includes the mouth of Alewife Brook in Cape Elizabeth. The north facing beach is the subject of geoarchaeology investigation as it demonstrates significant late Holocene changes in beach composition and includes Native American occupation. At this site we have analyzed hurricane and storm activity as well as the risk to archaeological sites in the matrix from erosion.

Figure 3. USGS Map of Alewife Brook, Cape Elizabeth, and the Ready Site (USGS, 2018).

Figure 4. Google Earth image of Bear and Malaga Islands (Google Earth, 2020).

MALAGA ISLAND

The second location analyzed is located between Bear and Malaga Islands off the coast of Phippsburg. This location is strategic relative to public education of Maine land trusts. The mixed-race fishing community who inhabited Malaga Island (ca. 1867-1912 AD) is well known regionally and was featured in a 2012 exhibit at the Maine State Museum. This area was vibracored in the summer of 2007, and the sample is utilized in the ANT 204, Gulf of Maine class. Those cores provided an uncorrected radiocarbon date of 3,800 +/- 30 BP (Beta Analytic Inc.) on the transition from the once one island to the current day two islands (Malaga and Bear). This location and the vibracores associated with it are rich with marine shellfish offering us the ability to study the changing conditions such as water temperature and sea-level rise, as well as when the arrival of invasive species such as the common periwinkle (*Littorina littorea*) took place (a topic of great scientific debate). The data we have collected at this location will be immensely useful in hypothesis testing.

Figures 5 & 6. View of intertidal zone between Malaga and Bear Islands, taken from Malaga, facing west. Note the dredge lines in the sand created by the process of collecting oysters and clams by local fishermen.

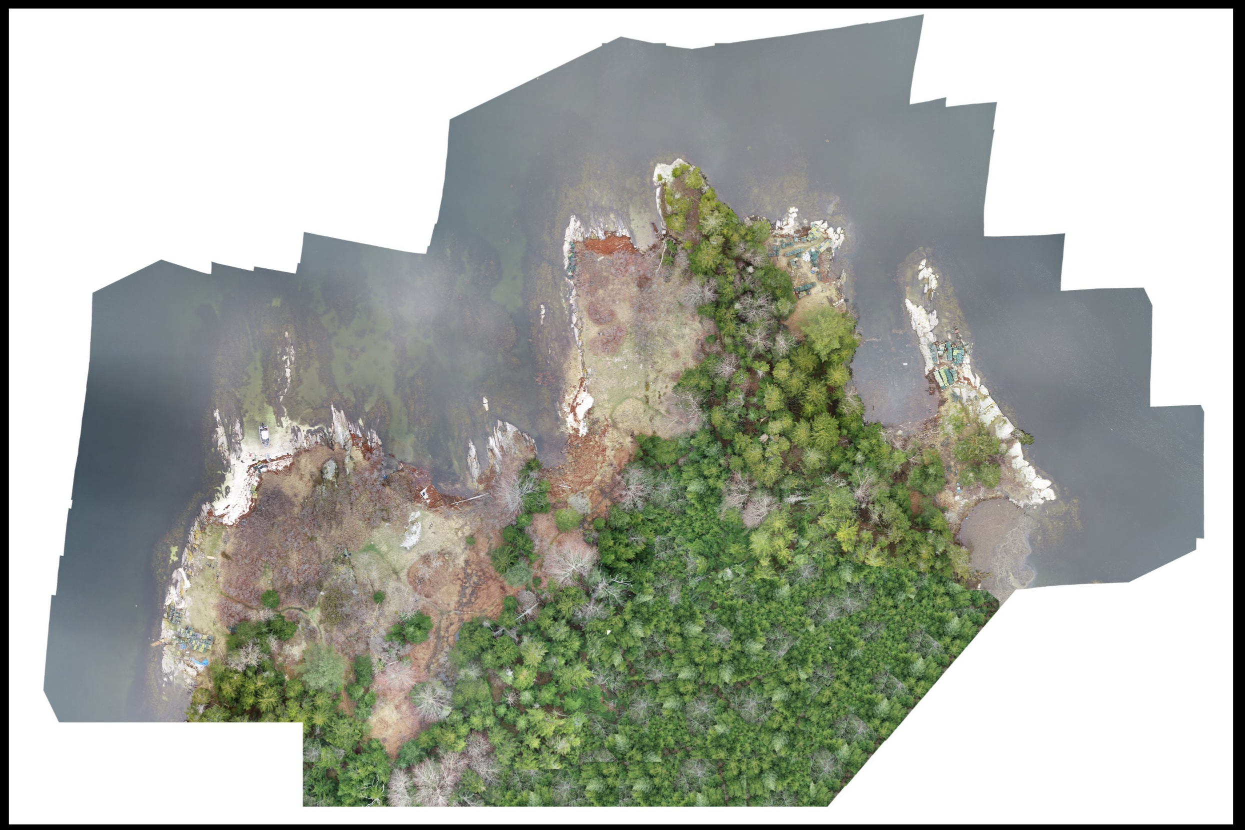

Figure 7. Orthomosaic map of the North end of Malaga Island. Created by Anthony Viola using drone mapped images that were collected August 2019. The image showcases the tree cover of the island and its bedrock features.

Figure 8. Drilling vibracore tubes in the intertidal zone between Bear and Malaga Islands, August 2019. The -1.4 ft tide afforded us the opportunity to core in this area.

Figure 9 Setting up vibracore equipment in the intertidal zone between Bear and Malaga Islands, August 2019. We had one hour to collect samples due to the rising tide.

Figure 10. Stratigraphic profile of the top one meter of vibracore 10 taken between Bear and Malaga Islands in northern Casco Bay. Close up photos for fresh cut of the tube (NDH 2019)

Figure 11. Stratigraphic profile of the bottom one meter of vibracore 10 taken between Bear and Malaga Islands in northern Casco Bay. Close up photos for fresh cut of the tube (NDH 2019)

Figure 12. Drone mapped image of Alewife Brook, the Ready Site and Murry Marsh. Created by Anthony Viola, September 2019.

Figure 13. Plank boardwalk in the center of Murry Marsh, adjacent to Alewife Brook, Cape Elizabeth, October 2019. Note the invasive phragmites. Standing in the center of the marsh, facing east.

Figure 14. In-situ aluminum vibracore in the Murry Marsh, adjacent to Alewife Brook, Cape Elizabeth, October 2019. Note the wooden plank boardwalk in the center of the marsh, facing north.

Figure 15. Stratigraphic profile of the East wall of Test Pit A at the Ready Site, Cape Elizabeth, October 2019.This test pit was excavated at 10 cm per level, with a total depth of 160 cm. Note the dark sediment between L11 and L13.

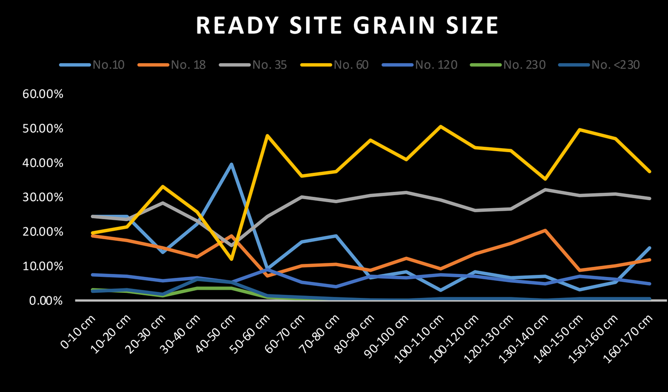

Figure 16. Grain size figures based on samples collected from the Ready Site, Cape Elizabeth, October 2019. Samples were run through a Gilson Model 705 sifter and separated by size ranging from 10 to <230 screens.

Figure 17. Excavated Test Pit A at the Ready Site, Cape Elizabeth, October 2019. This was one of two test pits that were excavated as part of the Fall 2019 Archaeology Field School course at USM.

Figure 18. Drilling vibracore tube in zone between Malaga and Bear Islands, August 2019.

Coastal evolution has been a long-term focus of geology at the Climate Institute at the University of Maine Orono and at the Maine Geological Survey. A carefully calibrated Gulf of Maine sea-level curve has been constructed using important marine data from Casco Bay. All the methods incorporated in those studies including calibration of time, geological changes, and aspects of mineralogy and chemistry are the same as methods we have used in our research. Greater attention to plant and animal species in the selected sites have afforded an opportunity to refine changes in the land environment. We have selectively sampled in areas at the Ready Site that had not been sampled to date and have analyzed the long-axis between Malaga and Bear Islands. This has allowed us to expand upon previously tested areas at each site, as there had already been 9 cores taken on Malaga Island and 30 at the Ready Site.

Instruments used for analysis:
- The sedimentology lab in Bailey Hall includes a Gilson Model 705 sifter with standard USGS brass screens, as well as a Mettler PO 6100 scale. We used these instruments to perform sediment analysis of the cores we took from each site. Figure 16 shows the grain size data from the Ready Site cores.
- USM also has two X-ray fluorescence spectrometers in Bailey Hall that were both paid for using former National Science Foundation grants. We plan on using these instruments to perform geochemistry analysis in the future but were stalled by the COVID-19 crisis.

Common Name	Latin Name	0-5	5-10	10-15	15-20	20-25	25-30	Total
Common Periwinkle	*Littorina littoria*	213	265	217	189	29	9	922
Smooth Periwinkle	*Littorina obtusata*				23	2	1	26
Rough Periwinkle	*Littorina saxatilis*	15	6		2	2	2	27
New England Dog Whelk	*Illyanassa trivitattus*	1			4		4	9
Waved Whelk	*Buccinum undatum*					4		4
Mud Dog Whelk	*Illyanassa obsoleta*		5	1				6
Dogwinkle	*Nucella lapillus*	4	1	20	4	1	2	32
Northern Moon Snail	*Lunatia heros*				3	5		8
Oyster Drill	*Urosalpinx cinerea*				2		1	3
Common Slipper Shell	*Crepidula fornicata*					1		1
Soft-Shell Clam	*Mya arenaria*	32	35	8	219	103	38	435
Blue Mussel	*Mytilus edulis*	20	34	14	239	133	15	455
Northern Quahog	*Mercenaria mercenaria*				3	4	4	11
Bay Scallop	*Aequipectin irradians*		11	2	28			41
Surf Clam	*Spisula solidissima*	1						1
Total								1981

Figure 19. Catalog of univalves and bivalves found in each 5 cm level of VC-8 collected from Malaga Island in 2017. Note the abundant appearance of the invasive species *Littorina littorea* starting at 15-20 cm. *L. littorea* was likely introduced to the North Atlantic region by British ships in the early 19th Century.

PUBLIC EDUCATION & THE GULF OF MAINE

The cores and research from these two sites have been integrated into the teaching curriculum of GYAY at the Muskie School of Public Service and have been formalized for use in lab exercises in multiple classes. Sedimentology, species identification, radiometric dating and X-ray fluorescence will provide the most complete analysis of microscale changes in the late Pleistocene and Holocene environments.

Within the field of archaeology, sea-level rise and coastal erosion are at the forefront of research and concern. These environmental impacts will destroy thousands of coastal archaeological sites in the coming years, as well as wreak havoc on coastal communities. With greater knowledge of how quickly sea-levels have risen in the past, we can determine which sites are most at risk. This research, assisted by Maine Coast Heritage Trust and other land trusts in coastal Maine, will, we hope, influence future policy and municipal planning decisions around sea-level rise.

Figure 20. Drawing out test pit configuration at the Ready Site, Cape Elizabeth, October 2019.

Figure 21. The vibracore team at Malaga Island, August 2019 (left to right) Anthony Viola, David Spidaliere, Robert Sanford, Jim Koehling.

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